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THERMO AND PHOTOLUMINESCENCE OF SILICATE LASER GLASS DOPED WITH NEODYMIUM

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The luminescence and thermoluminescence have been measured in vitreous materials doped with Nd^{3+}. The luminescence spectra show a maximum at 400 nm and a shoulder at about 440 nm. The measured global thermoluminescence shows a broad band with a maximum at 270 ^{o}C, which suggests a continuous distribution of electron traps induced by ionizing radiation. Thermoluminescence measured through two optical filters which transmit at about 400 nm and 440 nm wavelength shows a structured behavior with two glow peaks at 270 ^{o}C and 330 ^{o}C. This apparently contradictory behavior has been explained by the existence in this material of a continuous distribution of trap levels and a discrete distribution of recombination levels. The 270 ^{o}C and 330 ^{o}C glow peaks have been interpreted as being due to recombination of the electrons released from electron traps with O^{2-} and Nd^{3+} hole centers. Due to the high stability of the defects induced by the radiation observed from thermoluminescence measurements, this material could be used as a new radiation detector.

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1. Introduction

Due to the large applicability in the field of radiation detection and dozimetry, the family of the materials which presents thermoluminescence peaks under X-irradiation, grows continuously.

The most frequently used materials are composites with crystalline powders in plastic matrix. Recently, the researchers attention was canalized on glass materials doped with metals from the rare earth family (Nd and Eu being the most frequently used).

For binary silicate glasses having the composition 71.5% SiO_2 and 28.5% Na_2O, there were reported [1] two thermoluminescence peaks at 75 ^{o}C and at 125 ^{o}C, for moderate irradiation doses. In the case of high irradiation doses, it was reported a single peak situated at an intermediate temperature (between the two temperatures previously mentioned).

Y. Kirsh [2] has reported a maximum of the thermoluminescence intensity at 130 ^{o}C for silicate glass filters doped with Nd and Ge. The corresponding emission spectrum presents two peaks at 400 nm and 520 nm respectively. It was suggested that the 400 nm peak is due to the electrons recombination with trap centers represented by O^{2-} holes and that the 520 nm peak corresponds to the recombination with trap centers represented by Nd^{3+} holes.

2. Experimental results and discussions

This paper presents the results of the photoluminescence and thermoluminescence measurements on a silicate laser glass doped with Nd, obtained in the laboratories of the National Glass Institute, Bucharest, Romania. Measurements have been performed at the National Institute of Materials Physics, Bucharest, Romania. After a previous X-irradiation, the thermoluminescence was measured using an experimental equipment, the heating rate being 1.12 deg/sec. For the fotoluminescence measurements, standard equipment was used.

Fig. 1 presents the global thermoluminescence curve (a), the thermoluminescence curve (b) for a Schott Jena optical filter UG3 transmitting in the “blue” spectral zone and the thermoluminescence curve (c) for a Schott Jena optical filter VG6 transmitting in the “yellow” spectral zone.

The aspect of the (a) curve is typical for amorphous materials having a continuous distribution of the electronic trap energy levels. Table 1 presents the kinetic parameters obtained by fitting the experimental curve with the theoretical one. The analytical expression for the theoretical curve is:

$$I(T) = -\frac{dn}{dt} = S' n^b \exp\left(-\frac{E}{kT}\right) \quad (1)$$

where I = the luminescence intensity;
n = the free trap concentration;
b = the kinetic order;
S’ = the frequency factor;
E = the activation energy.

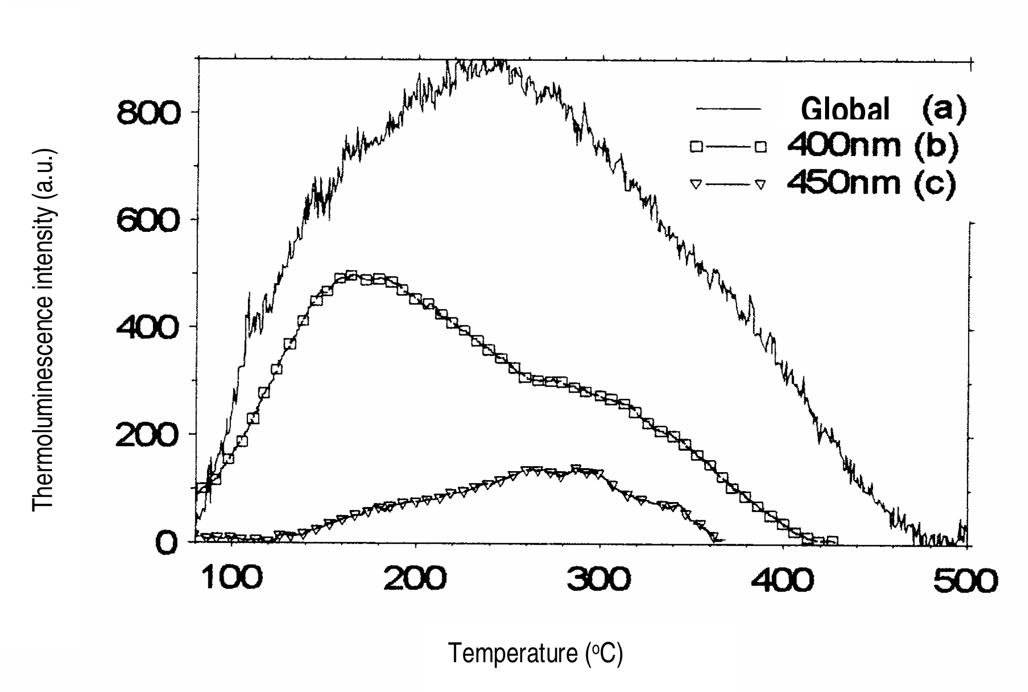

Fig. 1. The thermoluminescence intensity at room temperature for the X-irradiated Nd^{3+} silicate laser glass.

Table 1. Calculated kinetic parameters.

T_m (°C)	S’ (s^{-1})	E (eV)	b
132	$2.0 \cdot 10^{11}$	1.00	2.4
185	$1.8 \cdot 10^{12}$	1.22	2.4
239	$3.2 \cdot 10^{12}$	1.40	2.4
297	$4.8 \cdot 10^{12}$	1.57	2.4
370	$5.2 \cdot 10^{12}$	1.78	2.4

The used method was the “best fit” by the approximation of the experimental thermoluminescence curve with the sum of five individual peaks (Fig. 2). The obtained results give some qualitative information about the range of the activation energy. For the studied glass this range is 1.0 – 1.8 eV, moderately shifted compared with the reported 0.89 – 1.72 eV activation energy range for silicate optical filters [2]. Another difference is in the intensity and repartition of the peaks.

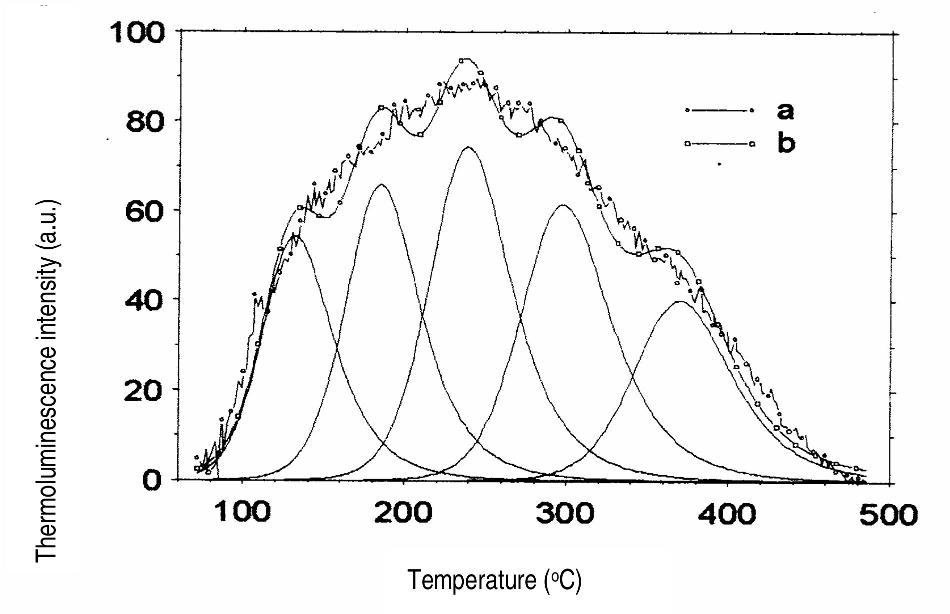

Fig. 2. The decomposition of the thermoluminescence curve using the "best fit" method:
a) Experimental curve
b) Theoretical curve

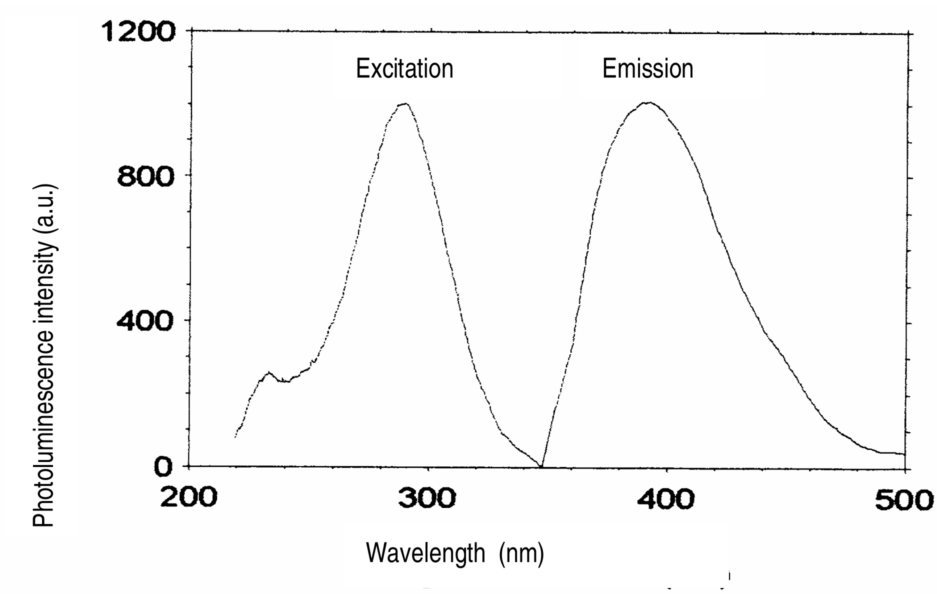

Fig. 3. The photoluminescence of the Nd^{3+} silicate laser glass.

The left part of Fig. 3 presents the excitation of the photoluminescence and the right one, the emission. It can be seen that the excitation of the emission bands is situated in the spectral zone where the material begins to absorb. This zone is known, in the crystalline materials terminology, as the fundamental band edge. In emission, a peak situated at 400 nm and a "shoulder" at 440 nm are observed. The observed thermoluminescence using optical filters that transmit at 4oo nm (Fig. 1b) and

450 nm (Fig.1c) respectively, presents different appearance. This indicates that the energy levels of the recombination centers have a discrete character.

The large number of the chemical components of the investigated glass could explain a continuous distribution of the electronic trap levels.

The luminescence at 400 nm and 440nm are done by the electron recombinations with trap centers represented by O^{2-} and Nd^{3+} holes respectively. This interpretation is in accordance with the results presented in [1].

3. Conclusions

The positioning of the global luminescence curve in a relatively high temperature range demonstrates the thermal stability of the defects induced by irradiation. This observation indicates that the investigated glass could be used as a new radiation detector material.

References

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